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Alchemy in the Ancient World: From Science to Magic

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"Alchemy" is the anglicised Byzantine name given to what its practitioners referred to as "the Art" (τέχνη) or "Knowledge" (ἐπιστήμη), often characterised as divine (θεία), sacred (ἱερά) or mystic (μυστική).[1] While this *techne* underwent many changes in the course of its life of over two thousand years (and there are traces of it even in modern times, as I will discuss), a recognisable common denominator in all the writings is the search for a method of transforming base metals (copper, iron, lead, tin) into noble (electrum, gold or silver).[2] There is unfortunately no modern critical edition of any of these writings (the extant editions being old or uncritical or both), though the Budé has begun the process.[3] In this essay I sketch the background and origins of the ancient alchemy, as well as its later transmutation into a mystical art of personal transformation. Finally I turn to the modern period and briefly examine the influence of this mystical tradition in our own world-picture.

Background

I begin with the first evidence of human chemical technology, which takes us back, well before the ancient period of merely 2,000 years ago, to the Palaeolithic Middle Pleistocene of 200,000 years ago—and the mastery of fire.[4] The achievement of this first controlled chemical reaction marks a

[1] W. Gundel, "Alchemie," *RAC* I (1950) 239–60, esp. 240–41; E. O. von Lippmann, *Entstehung und Ausbreitung der Alchemie* (Berlin 1919) I 293–314; E. Riess, "Alchemie," *RE* I (1894) 1338–55, esp. 1338–39.

[2] See for example Zosimus 3. 11 = M. P. E. Berthelot, *Collection des anciens alchimistes grecs* (= *CAAG*) II (Paris 1888) 145–48 Greek, 148–50 French; F. S. Taylor, "A Survey of Greek Alchemy," *JHS* 50 (1930) 109–39, esp. 127; Riess (previous note) 1351–52; Gundel (previous note) 249–50.

[3] For the judgement on the editions see Gundel (above, note 1) 239; the Budé begins with an edition of the Stockholm and Leiden papyri by Robert Halleux: *Les alchimistes grecs* I (Paris 1981); see H. D. Saffrey (therein) xiv–xv for their plans.

[4] S. R. James, "Hominid Use of Fire in the Lower and Middle Pleistocene: A Review of the Evidence," *Current Anthropology* 30 (1989) 1–26; M. Barbetti, "Traces of Fire in the Archaeological Record, Before One Million Years Ago?," *JHumEvol* 15 (1986) 771–81; C. K.

radical break with prior technology, the significance of which remained part of human memory down to the first millennium B.C. as revealed in the Prometheus Myth of the Greeks (Hesiod and Aeschylus) and the fire-worship of the Persians.[5]

Fire was and still is used in religious and magical rites; it is also the source of the second major advance in chemical technology: the production of an artificial substance. No doubt (though we lack positive proof) fire was used for cooking food and hardening wood—themselves important and mysterious processes (why after all should destructive heat make things harder and more durable?). But 26,000 years ago (one cycle of the precession of the equinoxes), south of what is now Brno in Czechoslovakia our ancestors first produced a new material having properties entirely dissimilar to those of the parent material—I mean baked clay.[6] But this new material was not to be used for pottery until a period more than twice as long as all of recorded history had passed—the people at Dolni Vestonice seem to have been chiefly interested in causing their molded animal figurines to explode on firing. This is relatively easy to accomplish with a sufficiently wet and thick clay body (though harder with loess, the raw material at Dolni)—potters must be taught (as I know by experience) to build or throw thinly. These explosions were probably ritualistic (the archaeologists often interpret the unknown as the sacred: *omne ignotum pro sacro*)—I am reminded of the fire-cracked Chinese oracle bones.

Fire hardened clay, and this miracle material came to be more common than stone, in the form of pottery vessels (the original form of which was probably clay-lined baskets). After the Agricultural Revolution fire was used not only to cook but to *bake*.[7] This again marks a decisive step—that fire hardened and preserved wood, bone, clay and food had long been known. The new magic was leaven—the invisible yeast preserved by bakers in sourdough (as fire was in fennel-stalks)—which transformed clay-like dough into raised bread. Again the symbolism was powerful enough after millennia to lodge at the core of Christianity.

Doubtless Neanderthals like jackdaws collected shiny rocks. Among these were pyrites, the most valuable, the fire-stone, the fire-starter, as well as bits of copper and gold of no apparent value (*we* have come so far that pyrites is now called "fool's gold").[8] At some point it was discovered that

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Brain and A. Sillen, "Evidence from the Swartkrans Cave for the Earliest Use of Fire," *Nature* 336 (1988) 464–66. I am indebted to Stan Ambrose (University of Illinois, Anthropology) for these references.

[5] Cp. R. J. Forbes, *Studies in Ancient Technology* (= *SAT*) VI (Leiden 1966) 1–13.

[6] P. B. Vandiver, O. Soffer, B. Klima and J. Svoboda, "The Origins of Ceramic Technology at Dolni Věstonice, Czechoslovakia," *Science* 246 (1989) 1002–08.

[7] Cp. Forbes, *SAT* VI (1966) 58–67; W. Krenkel, "Vom Korn zum Brot," *Das Altertum* 11 (1965) 209–23.

[8] Forbes, *SAT* VIII (1971) 8–28, 157 and IX (1972) 29–34.

the latter stones were soft enough that they could be carved like tough wood or bone, later still that they could like stiff dough or clay with difficulty be pounded into shapes. This hammering hardens the copper. The thought must have soon occurred—perhaps this stuff could be further hardened like clay, wood, bone in the fire? It was tried—and the failure was a source of wonder. Copper does not, like clay or bone, fracture if heated and quenched, nor does it harden—but rather it becomes softer! This made it easier to hammer. These early discoveries seem to have occurred in Armenia or North Iran, about seven thousand years ago.[9]

The earliest copper finds in Mesopotamia are at Tepe Gawra (4000–3500 B.C.)—a site to which I will refer again.[10] Just a bit later we have the earliest dated smelted copper (and copper slag) from Tepe Yahya in Iran (3800 B.C.), and at about the same time there is evidence of copper smelting in Egypt.[11] Smelting was probably discovered accidentally in a pottery kiln (kilns are first recorded by archaeologists at this time)—green malachite was reduced to red copper.[12] This was a magical transformation, like the firing of clay and the baking of bread, and represents the first artificial production or imitation of a natural substance—specifically the production of a valuable metal from something to which the metal has *no* resemblance or known connection.

Near Ur of the Chaldees at Al 'Ubaid have been found the earliest examples (from ca. 3500–3200 B.C.) of the deliberate production of tin-bronze.[13] It is not clear just how this was done, but from an alchemical point of view the most significant fact is that it *was*. This was probably a Sumerian discovery, as only their language distinguishes clearly between copper and bronze: copper is *urudu* and bronze *zabar*.[14] By doing something to a red metal the Sumerians produced a yellow metal (which was more

[9] A. Lucas, *Ancient Egyptian Materials and Industries*[4], ed. J. R. Harris (London 1962) 199–217 and Forbes, *SAT* VIII (1971) 20 and IX (1972) 29–34 on annealing of copper; R. F. Tylecote, *A History of Metallurgy* (London 1976) 1 and Forbes, *SAT* VIII (1971) 17–25 on locale.

[10] Tylecote (previous note) 9.

[11] Tylecote (above, note 9) 5–9; see R. F. Tylecote and H. McKerrell, "Examination of Copper Alloy Tools from Tal Y Yahya, Iran," *BullHistMetallGroup* 5 (1971) 37–38.

[12] Forbes, *SAT* VIII (1971) 28; Tylecote (above, note 9) 5–6; H. H. Coghlan, "Some Experiments on the Origin of Early Copper," *Man: A Monthly Record of Anthropological Science* 39 (1939) 106–08; idem, "Prehistoric Copper and Some Experiments in Smelting," *TransNewcomenSoc* 20 (1939/40) 49–65; A. Lucas, "The Origin of Early Copper," *JEA* 31 (1945) 96–97; H. H. Coghlan, *Notes on the Prehistoric Metallurgy of Copper and Bronze in the Old World*, Pitt Rivers Museum, U. of Oxford, Occasional Papers on Technology 4 (Oxford 1951); George Rapp, Jr., "Native Copper and the Beginning of Smelting: Chemical Studies," in *Early Metallurgy in Cyprus 4000–500 B.C.*, ed. J. D. Muhly et al. (Nicosia 1982) 33–38.

[13] Tylecote (above, note 9) 9.

[14] Forbes, *SAT* IX (1972) 89, 115—cp. the Egyptian words, p. 55; see also M. P. E. Berthelot, "Sur le cuivre des anciens," *Annales de chimie et de physique* (6) 12 (1887) 141–43.

easily cast and could be made far harder).[15] The further successes of prehistoric metallurgy cannot detain us here,[16] though lead,[17] tin,[18] antimony[19] and iron[20] were extracted and brass was invented.[21] Two processes for producing gold and silver I must mention. Silver was rarer than gold in Egypt; by about 2000 B.C. it was being produced in the Near East from argentiferous galena by cupellation—that is the galena was roasted to produce lead, which was oxidised in a fired clay crucible leaving only the silver.[22] By the fifth century B.C. the Egyptians had learned the long-known cementation process by which impure gold or electrum is heated with clay, sand and salt in a closed vessel to produce refined or purified gold. Both processes must have seemed magical and arbitrary.[23]

I have discussed prehistoric and early metallurgy—the connection to alchemy is clear. Now I must make a detour into Egyptian and Sumerian chemistry—also connected with alchemy—to mention two other important artificial substances: glass and beer.

The first artificial stone was fired clay. The Egyptians were using a gypsum mortar (similar to our cement or concrete) from predynastic times, and it is they who invented faience (a fired ground-quartz paste).[24] We do not

[15] T. T. Read, "Metallurgical Fallacies in Archaeological Literature," *AJA* 38 (1934) 382–89; J. R. Partington, "The Discovery of Bronze," *Scientia* 60 (1936) 197–204.

[16] A. Neuburger, *Technical Arts and Sciences of the Ancients* (London 1930) 8–27; Lucas (above, note 9) 195–257; Forbes, *SAT* X (1972) 152–66; J. F. Healy, *Mining and Metallurgy in the Greek and Roman World* (London 1978).

[17] Lead was smelted from galena: see Forbes, *SAT* VIII (1971) 196–266.

[18] Tylecote (above, note 9) 14–29 and Forbes, *SAT* IX (1972) 134–52, 166 ff. discuss tin; W. Lamb, *Excavations at Thermi* (Cambridge 1936) 171–73, 215, Pl. XXV records an EBA pure tin bracelet (object 30. 24).

[19] Cp. Pliny, *HN* 33. 33. 101–34. 104; Diosc. *MM* 5. 84 (99); M. P. E. Berthelot, "Métaux et mineraux provenant de l'antique Chaldée; sur les origines de l'étain dans le monde ancien," *Comptes rendues de l'Académie des Sciences* 104 (1887) 265–71 and "Sur quelques métaux et mineraux provenant de l'antique Chaldée," *Annales de chimie et de physique* (6) 12 (1887) 129–40, esp. 134–36 records the antimony bowl from Tello; for other antimony objects see: L. Cambi, "Sul metallo dei monili delle tombe del sepolcreto di Ponte S. Pietro," *Rend. Ist. Lombardo. Sci., Classe sci. matem. e natur.* 92 A, pt. 2 (1958) 167–72 "neolithic" (2500–2000 B.C.) antimony beads; L. Cambi and F. Cremascoli, "Sul metallo dei bottoni della tomba preistorica di Monte Bradoni presso Volterra," ibid. 91, pt. 2 (1957) 371–77 antimony buttons of "bronze age"; R. Virchow, "Neue Erwerbungen aus Transkaukasien, insbesondere eine Fenterume und Schmücksachen aus Antimon," *Verh. Berl. Gesell. Anthropol. Ethnol. Urgesch.* (1884) 125–31.

[20] On iron see Read (above, note 15); Tylecote (above, note 9) and Forbes, *SAT* IX (1972) 187–305.

[21] See E. R. Caley, "Orichalcum and Related Alloys," *ANS NNM* 151 (1964). Zinc itself (alloyed with copper to make brass) was apparently also known: Str. 13. 1. 56 (610) calls it ψευδάργυρος and cp. M. Farnsworth, C. S. Smith and J. L. Rodda, "Metallographic Examination of a Sample of Metallic Zinc from Ancient Athens," *Hesperia* Suppl. 8 (1949) 126–29, Pl. XVI.

[22] Tylecote (above, note 9) 38; Forbes, *SAT* VIII (1971) 196–266.

[23] Forbes, *SAT* VIII (1971) 180–81; Lucas (above, note 9) 224–35.

[24] Lucas (above, note 9) 74–79 mortar, 156–78 faience.

know where or when glass was first made, but it has been found in Egypt from 2500 B.C., in Mesopotamia a bit later, usually in the form of beads.[25] Popular in Egypt primarily during the New Kingdom, glass long remained a fixture of Mesopotamian technology—in fact the oldest extant glass recipe, from the seventeenth century B.C., is a Sumerian–Babylonian cuneiform tablet.[26] The writer "anticipates" the deliberate obscurity of later alchemical texts, but the recipe is recognizably that for a green glass. Later seventh-century B.C. recipes produce soda glass and crown glass equivalent to our modern glasses—but the recipes include the building of human embryos into the furnace walls. One of the Egyptian recipes found its way into the Greco-Roman tradition as *caerulium*: sand, green malachite, chalk and salt were fused at just the right temperature to produce a sky-blue glassy stone[27]—without any embryos.

The fermentation of sweet fruit juices—wine—probably goes back to the Palaeolithic and occurs spontaneously due to the presence of the yeast of the mold family found on the fruit skins.[28] This miracle too was long remembered as such—the Greeks worshipped Dionysus as the bringer of wine, wine is symbolic of the blessings of God in the Hebrew Scriptures and wine is, with bread, one of the sacred substances of the Christian religion. The connection of wine specifically with alchemy I will address shortly. The invention of beer is often credited to the Egyptians—the Greek historian Diodorus Siculus (1. 20. 4) credits it to the god Osiris. The process of malting (soaking grain in water till it begins to sprout) generates the sugar necessary for fermentation—the whole process is far more complex than the production of wine.[29] A neo-Babylonian tablet of the fifth–fourth century B.C. preserves the Sumerian beer recipe:[30] we even know how the Sumerians and Egyptians drank it—through straws (Fig. 1). This beer process is also recorded for us in Greek writings—in the

[25] Lucas (above, note 9) 179–84; J. R. Partington, *The Origins and Development of Applied Chemistry* (London 1935; repr. New York 1975) 119–32; Neuburger (above, note 16) 152–64; A. C. Kisa, *Das Glas im Altertume*, 3 vols. (Leipzig 1908); M. L. Trowbridge, *Philological Studies in Ancient Glass*, U. of Illinois Studies in Language and Literature 13. 3–4 (1928) 231–436.

[26] C. J. Gadd and R. C. Thompson, "A Middle-Babylonian Chemical Text," *Iraq* 3 (1936) 87–96; R. C. Thompson, "Assyrian Chemistry," *Ambix* 2 (1938) 3–16; idem, *Dictionary of Assyrian Chemistry and Geology* (Oxford 1936) xxi–xxxvi, 194–97.

[27] Pliny *HN* 33. 57. 161–64; Vitr. 7. 11. 1; Theophr. *De Lap.* 70, 98–100; Diosc. *MM* 5. 91 (106); see Partington (above, note 25) 117–19; Forbes, *SAT* III (1965) 224–25.

[28] Forbes, *SAT* III (1965) 62–64, 72–74; Neuburger (above, note 16) 105–09; Lucas (above, note 9) 16–24.

[29] Forbes, *SAT* III (1965) 65–70; J. P. Arnold, *Origin and History of Beer and Brewing* (Chicago 1911) 41–184.

[30] L. F. Hartmann and A. L. Oppenheim, "On Beer and Brewing Techniques in Ancient Mesopotamia," *JAOS* Suppl. 10 (1950). The figures of the beer-drinkers are drawn from their Plates I and II.

encyclopedia of alchemy written ca. A.D. 300 by Zosimus[31]—where it is explicitly connected with the alchemical transformation of base metals to gold.[32]

Origin

The techniques of the Egyptians and Mesopotamians represent the foundation stones of the edifice we call alchemy. Built onto this *techne* was the Greek philosophy of nature. So far as we know these Near Eastern peoples were not inclined to seek explanations for these processes. But from the times of Thales (seventh century B.C.) the Greeks began to develop a natural philosophy, seeking to understand the world not in terms of the actions of anthropomorphic deities alone but also in terms of "natural" forces. The earliest of these thinkers were hylozoistic monists—they explained everything in terms of one thing, which was some material endowed with life-like properties. Thus Thales thought everything was originally water, out of which earth and living things grew; others suggested air or fire.

Empedocles, Plato and Aristotle contributed to the development of the "Four-Element" Theory which persisted down to the seventeenth century A.D. (Shakespeare and Milton). In this model everything was made of some combination of the four elements (Fire, Air, Water, Earth), related as in Fig. 2.[33] In this theory the two pairs of primary opposites Hot/Cold, Dry/Wet—themselves like our modern quarks never separately observable—combine to produce the four elements. Each element has its natural place and a natural motion towards that place (up/down). To explain the perpetual circular motions of the seven planets Aristotle added a separate and distinct material "first body" which he called *aither*, and a non-material "fifth substance" to explain the soul. Later in the third century B.C. these two concepts were blurred and merged under the name "quintessence."[34]

To this last point I shall return, but first I must explain the chemical theories which result from this four-element model. First, elements (*stoicheia*) may transform into one another by a change in their constituent opposites—thus Water becomes Earth when the Wet leaves and the Dry comes, a mixture of Fire and Water may become Earth plus Air by a kind of double decomposition reaction (Cold/Wet + Hot/Dry → Cold/Dry +

[31] Lucas (above, note 9) 14; Forbes, *SAT* III (1965) 70 and Arnold (above, note 29) 85, all from Chr. G. Gruner, *Zosimi Panopolitani de zythorum confectione fragmentum* (Sulzbach 1814) *nondum vidi.*

[32] See Berthelot, *CAAG* I. 2 (1887) 7 Greek (*s.v.* ζύμη) = 7 French (*s.v.* levain); Riess (above, note 1) 1352–53. Cp. n. 72 below.

[33] See esp. J. E. Bolzan, "Chemical Combination According to Aristotle," *Ambix* 23 (1976) 134–44.

[34] P. T. Keyser, "Horace *Odes* 1. 13. 3–8, 14–16: Humoural and Aetherial Love," *Philol.* 133 (1989) 75–81, esp. 76–77. Fig. 2 is taken from this article.

Hot/Wet), and (hardest of all) Water may become Fire if both Cold and Wet pass away and Hot and Dry come to be. So much for atomic physics—chemistry involves mixtures or blends of the four elements. Ever since Anaximenes had postulated that the elements transform into one another by rarefaction and condensation, the notion that mathematics might enter chemistry was about. Plato in the *Timaeus* tries to construct the elements from fundamental triangles grouped into four of the five "Platonic" solids (thus betraying his Pythagoreanism). Aristotle too allows arithmetic—there are differences in degree of the four elements and a compound will exhibit a certain ratio of combination: this is effectively Dalton's "Law of Definite Proportions" of 1808.

This theory remained not without application.[35] For example we read that substances made of Earth plus Water are solidified by heat because it drives off the water, and by cold which drives out the natural heat—in this case (if Earth predominates) heat will again liquify them. The example of iron is given—it can be melted by extraordinary heat (and this is part of the making of χάλυψ, steel).[36] Again, gold, silver and other metals are composed of water for they are all melted by heat. Aristotle wisely refrained, however, from assigning specific numbers to the compounds (cp. *Meteor.* 4. 10 [389a7–23]). Plato (who also made metals of water) did assign definite numerical ratios to the elemental transformations: 2 Fire = 1 Air, 2.5 Air = 1 Water (*Tim.* 56e).

Aristotle does not mean that ordinary water and earth combine to form substances such as gold or iron. In fact both stones and metals are formed by the agency of an ill-defined pair of "exhalations" (ἀναθυμιάσεις)—metals primarily by the moist exhalation, stones primarily by the dry. But all metals are affected by fire and contain some earth (from the dry exhalation)—only gold is not affected by fire.[37] Presumably the baser the metal the more earth or "dry exhalation" it contained. Plato too indicates that the water which forms metals is a special kind of which the best is gold (*Tim.* 58d, 59b): Pindar had already proclaimed water as best, together with gold which shines out (*Oly.* 1. 1, cp. *Isthm.* 5. 1–3).

Aristotle was president and chairman of his own university—his successor Theophrastus wrote a number of books in which he ventilated difficulties with the four-element theory (without suggesting a competing theory). For example he points out that fire is self-generating yet requires fuel, can be created but mostly by violence (i.e., not naturally: *De Igne* 1–5). More important for the rise of alchemy, he records a number of recipes for preparing artificial stones. He knows that yellow ochre (ὤχρα) when heated in closed airtight pots turns to red ochre (μίλτος: *De Lap.* 52–54).

[35] See I. Düring, *Aristotle's Chemical Treatise: Meteorologica Book IV* (Göteborg 1944).
[36] Forbes, *SAT* IX (1972) 218.
[37] D. E. Eichholz, "Aristotle's Theory of the Formation of Metals and Minerals," *CQ* 43 (1949) 141–46.

Again he gives recipes for making white lead (ψιμύθιον) and green verdigris (ἰός) by exposing lead and red copper to vinegar (to make the acetates: *De Lap.* 56–57). Finally from red cinnabar is made quicksilver (χυτὸς ἄργυρος) by pounding the red sandy substance mixed with vinegar in a copper mortar with a copper pestle (*De Lap.* 60). I draw attention to the interest in the color transformation as well as to the transformations between stony or earthy substances (cinnabar, white lead, verdigris) and metals (lead, copper, quicksilver). This is the sort of thing in which the alchemists were greatly interested. Singled out for remark is the method of producing brass (with a beautiful color) by mixing a certain earth with copper (*De Lap.* 49)[38]—Aristotle himself had already remarked of bronze production that the tin seems to disappear into the copper leaving only the color of the tin (*GC* 1. 10 [328b13–14]).

Physical Matters of Alchemy

Such scientific speculations contined throughout antiquity—theories were modified and reiterated. Alchemy proper began when a neo-Pythagorean writer applied magical notions of sympathy and antipathy to the Egyptian techniques sketched above.[39] This was the obscure but influential Bolus, who wrote under the name of Democritus about 200 B.C.[40] His treatise, *Physical and Mystical Matters*, is partly preserved in various alchemical MSS and contains recipes for imitating purple dye and a mystical vision whose message is, "Nature delights in nature, nature conquers nature, nature controls nature," followed by recipes for the imitation of gold.[41] These notions of sympathy were for the era very scientific—the Stoics believed in an all-pervasive *pneuma* (spirit) which bound the universe together in sympathy and this was used to justify astrology. The planets had been associated with metals by the Babylonians: Gold/Sun, Silver/Moon, Lead/Saturn, Electrum/Jupiter, Iron/Mars, Copper/Venus, Tin/Mercury (Fig.

[38] See the commentaries of E. R. Caley and J. F. C. Richards, *Theophrastus on Stones* (Columbus, OH 1956) and D. E. Eichholz, *Theophrastus: De Lapidibus* (Oxford 1965).

[39] See in general the references in note 1 above, and L. Thorndike, *History of Magic and Experimental Science* I (New York 1923) 193–99; H. Diels, *Antike Technik*[3] (Leipzig 1924; repr. Osnabrück 1965) 121–54; A. J. Hopkins, *Alchemy, Child of Greek Philosophy* (New York 1934); F. S. Taylor, *The Alchemists* (Oxford 1949); E. J. Holmyard, *Alchemy* (Harmondsworth 1957); R. J. Forbes, *SAT* I (1964) 125–48; J. Lindsay, *The Origins of Alchemy in Greco-Roman Egypt* (New York 1970).

[40] Diels (previous note) 121–54; M. Wellmann, "Bolos (3)," *RE* III (1897) 676–77; idem, "Die Georgika des Demokritos," *Abh. Preuss. Akad. Wiss., Phil.-Hist. Kl.* (1921) no. 4; idem, "Die Physika des Bolos Demokritos und der Magier Anaxilaus von Larissa," ibid. (1928) no. 7; idem, *Der Physiologus, Philologus* Suppl. 22. 1 (1930) esp. 81–111; W. Kroll, "Bolos und Demokritos," *Hermes* 69 (1934) 228–32; idem, "Sympathie und Antipathie in der antiken Literatur," *F&F* 10 (1934) 111–12; W. Burkert, "Hellenistische Pseudo-pythagorica," *Philol.* 105 (1961) 16–43, 226–46; J. H. Waszink, "Bolos," *RAC* II (1954) 502–08.

[41] Berthelot, *CAAG* II (1888) 41–56 Greek, 43–60 French.

3, upper right). Later texts make Tin/Jupiter and Mercury/Mercury.[42] The association of the planets with certain divinities is Babylonian, as the *Epinomis* attributed to Plato tells,[43] although Plato already in the *Timaeus* builds on the (probably universal) belief in the divinity of the planets (*Tim.* 38c–40d). And astrology is connected with alchemy from the beginning, for almost the earliest astrological text of which we have traces, that called Nechepso–Petosiris after the two Egyptian kings who allegedly wrote the thing (it is probably second century B.C.), quotes Bolus' mystical message, "Nature delights in nature, . . . "[44] (note that the order of the planets in Fig. 3 is the astrological order). Much discussion has been generated over the place where alchemy originated—probably it was indeed Alexandria in Egypt.[45] In any case all our earliest traces of it come from Alexandria. While the number of recipes preserved is too vast easily to survey, a few high points must be mentioned.

Bolus gives recipes using arsenic, antimony or mercury for transforming copper to silver (*Phys. Myst.* 4)—thus coloring the surface—gold is produced by tinting silver with sulfur (*Phys. Myst.* 7). But we often do not understand just what the alchemist was about—obscurity seems to have been paramount for him—or *her*. Two of our earliest extant treatises are by women. One is very obscure indeed although we know the authoress, Cleopatra (not the queen) sought to make gold: Fig. 4.[46] Note the symbolism of the Ouroboros (tail-eating) snake, and the inner circle of Greek (εἷς ἐστιν ὁ ὄφις ὁ ἔχων τὸν ἰὸν μετὰ δύο συνθήματα) "one is the snake which has the *ios* (rust?) after two compositions"; note as well the

[42] Berthelot, *CAAG* I (1887) 73–85, 92–106; for the later text see II (1888) 24–25 Greek, 25–26 French.

[43] *Epin.* 987a–d; J. R. Partington, "The Origins of the Planetary Symbols for the Metals," *Ambix* 1 (1937/38) 61–64; M. P. Nilsson, "Die babylonische Grundlage der griechischen Astrologie," *Eranos* 56 (1958) 1–11; G. L. Huxley, *The Interaction of Greek and Babylonian Astronomy* (Belfast 1964); B. L. van der Waerden, *Science Awakening* II (Oxford 1974) 186–87; cp. also J. L. E. Dreyer, *A History of Astronomy from Thales to Kepler* (New York 1953) 169.

[44] E. Riess, *Nechepsonis et Petosiridis fragmenta magica* I (Bonn 1890), II = *Philol.* Suppl. 6 (1891–93) 325–94; cp. also Forbes, *SAT* I (1964) 134; Taylor (above, note 39) 51–56 and R. Halleux, *Le problème des métaux dans la science antique*, Bibl. Fac. Philos. et Lettres. Univ. Liège 209 (Paris 1974) 149–60. The other early astrological text is that of Berossus: P. Schnabel, *Berossos und die babylonische-hellenistische Literatur* (Leipzig 1923; repr. Hildesheim 1968).

[45] On Babylonian influence, see J. Bidez, "Les écoles chaldéenes sous Alexandre et les Séleucides," *Brussels, Université Libre. Institut de Philologie et d'Histoire Orientales. Annuaire* 3 (1935) 41–89; for Babylonian origin see R. Eisler, "L'origine babylonienne de l'alchimie," *Rev. Synth. Historique* 41 (1925) 5–17 and idem, "Der babylonische Ursprung der Alchemie," *Chemiker Zeitung* 49 (1925) 577–78. For China see H. H. Dubs, "The Beginnings of Alchemy," *Isis* 38 (1947) 62–86 and J. Needham, *Science and Civilization in China* V. 2 (Cambridge 1974) 8–36. For Egypt, see the authorities cited in notes 1 and 39 above, and G. Goldschmidt, "Der Ursprung der Alchemie," *CIBA Zeitschrift* 5 (1938) 1950–80, 1983–85, 1987–88.

[46] Berthelot, *CAAG* I (1887) 132.

symbols for (L to R) mercury, silver (with the "filings" squiggle below?) and gold. But what does it all mean?

In the lower right is a distillation apparatus, to which I will return after mentioning the second female writer on alchemy: Maria the Jewess after whom the bain-marie (or double-boiler) is named.[47] Note the bain-marie just below the mystic circle; the τρίβικος, "three-armed still," is explicitly given as Maria's invention.[48] Apparently numerous pieces of apparatus were her inventions, but it seems that the bain-marie itself was known to Theophrastus (*De Odor.* 22).[49] It is not impossible that she made some modification or improvement—stills had been known for ages as well (to this point I shall return). One of her procedures involved the use of "our lead" or "four-body" (*tetrasoma*), an alloy of copper, iron, lead and tin which is "killed," corrupted and then whitened and yellowed to produce gold; another involved "salting" the base metal (this procedure was called *taricheia*, which is the ordinary word for mummification). The notion of preliminary corruption and later ennobling is consistent with Aristotle's doctrine of elemental change (as noted already). She also mentions the standard alchemical "divine water" usually interpreted as sulfuretted water (i.e. a solution of hydrogen sulfide or calcium sulfides) which was used in the yellowing stage.

Maria's *tribikos* was based on earlier stills. Since it is not usually realised how early is the evidence of distillation, allow me to digress a moment. Earlier I warned that Tepe Gawra would be mentioned again. It is from this site that the world's oldest still comes—a 3500 B.C. Sumerian device (Fig. 5). This seems to have been used to distill botanical essences—which would collect in the double rim and would later be sponged out, so the texts tell us.[50] The stages in the evolution of the alchemical still are shown in Fig. 6.[51] In the first century A.D. Greco-Roman writers record the distillation of mercury (Diosc. *MM* 5. 95 [110]) and pitch (Diosc. *MM* 1. 72. 3 [96]). Experiments have shown that the ancient styles of stills could easily have distilled the water off from vinegar to concentrate acetic acid, and, as well, could have been used to distill alcohol.[52] Maria's early stills (the *tribikos*) were made of copper—late in the first century A.D. blown glass was invented and she preferred glass for her later apparatus. From the first century A.D. we have reports of flaming wine, which cannot

[47] R. Patai, "Maria the Jewess: Founding Mother of Alchemy," *Ambix* 29 (1982) 177–97.

[48] Berthelot, *CAAG* I (1887) 139.

[49] Forbes, *SAT* III (1965) 32; Lippmann (above, note 1) 50.

[50] M. Levey, "Evidences of Ancient Distillation, Sublimation and Extraction in Mesopotamia," *Centaurus* 4 (1955) 23–33.

[51] F. Sherwood Taylor, "The Evolution of the Still," *Annals of Science* 5 (1945) 185–202, Fig. 14, repr. in Taylor (above, note 39) Fig. 43.

[52] A. R. Butler and J. Needham, "An Experimental Comparison of the East Asian, Hellenistic, and Indian (Gandhâran) Stills in Relation to the Distillation of Ethanol and Acetic Acid," *Ambix* 27 (1980) 69–76.

happen unless it is distilled, i.e. brandy (Pliny, *HN* 14. 6. 62–63 and Suet. *Aug.* 95. 4: the report of Suetonius is localised to Thrace, the home of Dionysus god of wine).[53] Studies of the available literary evidence indicate that it *was* sometime in the first century B.C. or A.D. that alcohol was first distilled.[54] The recipe is preserved by an early Christian writer "exposing" the tricks of the Gnostics, and these tricks have been traced to the magician and neo-Pythagorean Anaxilaus of Larissa (in Thessaly near Thrace) who was expelled from Rome in 28 B.C.[55] (Another recipe of Anaxilaus is preserved in one of the two alchemical papyri we have.)[56] Bolus, the original alchemist, wrote under the name of Democritus[57] of Abdera, which is also in Thrace. Why are Thessaly and Thrace so often mentioned? Thrace was, in Greco-Roman thought, the land of the magicians,[58] as was Thessaly.[59]

[53] M. P. Nilsson, *GGR* I[3] (Munich 1967) 564–68; J. G. Frazer, *The Golden Bough* VII (London 1913) 2–3.

[54] H. Diels, "Die Entdeckung des Alkohols," *Abh. K. Preuss. Akad. Wiss., Phil.-Hist. Kl.* (1913) repr. in *Kleine Schriften*, ed. W. Burkert (Hildesheim 1969) 409–41; and C. A. Wilson, "Philosophers, Īōsis, and Water of Life," *Proc. Leeds Philos. Lit. Soc., Lit. Hist. Sect.* 19 (1984) 101–219.

[55] Wellmann 1928 (above, note 40) 56–62; cp. Wilson (previous note) 152–54 and Diels 1913 (previous note) 21–35 (427–41 of reprint).

[56] *PStock* 2; see E. R. Caley, "The Stockholm Papyrus," *JChemEd* 4 (1927) 979–1002 and "The Leyden Papyrus," *JChemEd* 3 (1926) 1149–66, and the recent edition of both papyri by Halleux (above, note 3).

[57] For Democritus as a magician, see Pliny *HN* 24. 99. 156, 102. 160, 25. 5. 13 and 30. 2. 8–11. For modern comment, see M. P. Nilsson, *GGR* II[3] (Munich 1974) 534–35; J. E. Lowe, *Magic in Greek and Roman Literature* (Oxford 1929) 7 and E. Tavenner, *Studies in Magic from Latin Literature* (New York 1916) 20 n. 101, 56 n. 321.

[58] For Thrace as land of magic, see Cratinus Θρᾷτται (frr. 73–89 Kassel–Austin), Eupolis Βάπται (frr. 76–98 Kassel–Austin), Plut. *De def. orac.* 10 (415a), Horace, *Epode* 17. 56 (on Cotytto see A. Rapp, "Kotys," *LexikonGRM* II. 1 [1890–97] 1398–1403), and Pliny *HN* 30. 2. 7. For modern comment, see G. Kazarov, "Thrake (Religion)," *RE* VI A (1936) 472–551, esp. 548–51, Lowe (above, note 57) 10 and A. M. Tupet, *La magie dans la poésie latine* (Paris 1976) 142. Tupet 156, suggests Hekate was originally Thracian—she seems to be following L. R. Farnell, *Cults of the Greek States* (Oxford 1896–1909) II 507–09, who adduces Str. 10. 3. 21–22 (473), but J. Heckenbach, "Hekate," *RE* VII. 2 (1912) 2769–82, esp. 2780. 38–47 doubts and prefers SE Asia Minor on the evidence of the distribution of the cult sites.

[59] For Thessaly as land of magic, see: Menander, *Thettale* (cp. Pliny *HN* 30. 2. 7 and Kock, *CAF* III, Menander frr. 229–34); Plautus, *Amph.* 1043; Horace, *Epode* 5. 41–46, *Ode* 1. 27. 21–22, *Epistle* 2. 2. 208–09; Tib. 2. 4. 55–60; Prop. 1. 5. 4–6 and 3. 24. 9–10; Ovid, *Amores* 1. 14. 39–40 and 3. 7. 27–30, *Ars Amat.* 2. 99–104, *Rem. Am.* 249–52; Sen. *Phaedra* 420–23 and 790–92, *Medea* 787–811, *Her. Oet.* 465–72 and 523–27; Lucan 6. 413–830, esp. 434–91; Val. Fl. 1. 735–38, 6. 445–48, 7. 198–99, 7. 325–30; Pliny, *HN* 30. 2. 6–7; Statius, *Theb.* 3. 140–46 and 557–59, 4. 504–11; Mart. 9. 29. 9; Juv. 6. 610–12; Apul. *Met.* 2. 1; *Anth. Pal.* 5. 205. For modern comment, see W. H. Roscher, "Mondgöttin (Zauberei, Magie)," *LexikonGRM* II. 2 (1894–97) 3165–66, Tavenner (above, note 57) 20 n. 98, Lowe (above, note 57) 6–8 (she is a believer: "The spirit world is an established fact for all intelligent people; the desirability of communicating with it . . . is another matter," p. 2), and Tupet (previous note) 143, 163, 196, 210.

Distilled vinegar probably comes into another device, found in a burial site in the first century A.D. Mesopotamia, and associated with magicians. This object consisted of a sealed copper tube down the middle of which was suspended an iron rod: Fig. 7. The tube once contained a liquid, probably vinegar, and seems to have been an ancient wet-cell or battery. Modern tests show that it could generate about one half volt at a few milliamps. What could the device have been used for? The first publication suggested electroplating and even the physicist George Gamow agreed, but the technological context is absent. I have suggested a connection to the attested use of living electric rays (*torpedines*) in the first century A.D. as a local analgesic in cases of gout and headache, and modern clinical practice (transcutaneous electrical nerve stimulation) confirms that about one half volt at a few milliamps is effective.[60]

The plating of metals *was* practised in antiquity, by various more or less mechanical or thermal means: for example in Roman times a gold or silver amalgam was applied and the mercury boiled off (Vitr. 7. 8. 4; Pliny, *HN* 33. 20. 64–65, 33. 32. 100, 33. 42. 125, 34. 48. 162–63; *PLeydenX* 27 and 57). A more chemical process, called cementation or surface leaching, in which a base alloy of gold or of silver is attacked by substances which corrode away the base metal near the surface so that the object appears nobler, was also used: our earliest recipe for this is in Bolus, *Physical and Mystical Matters* 12.[61] Archaeological evidence suggests that this or some similar method of coloring metals was practised from a very early date in Mesopotamia and Egypt. Two Egyptian examples are especially instructive. In King Tut's tomb were found numerous gold rosettes which were colored purple. The American physicist Wood was called in to solve the problem and he determined that the gold contained 1% iron and traces of orpiment (native arsenic sulfide: As_2S_3) and that when such an alloy is cold worked and then heated a bit below red heat, a purple or violet color is produced.[62] To the empurpling of gold I will return in a moment. The second example concerns an Egyptian bowl and ewer of the V Dynasty in the Metropolitan Museum which have been shown to be arsenic plated, as well as an Anatolian bull figurine of the late third millennium B.C. similarly plated.[63] The alchemical texts speak of arsenic (or antimony) plating as a way of producing silver from copper: *PLeydenX* 23.

[60] P. T. Keyser, "The Purpose of the Parthian Galvanic Cells," *AIA Abstracts* 13 (1989) 46 and submitted. Fig. 7 is taken from this article.

[61] Berthelot, *CAAG* II (1888) 46; cp. *PLeydenX* 15, 25 and 69. See H. Lechtman, "Ancient Methods of Gilding Silver—Examples from the Old and the New Worlds," in *Science and Archaeology* (Cambridge 1970) 2–30, and L. H. Cope, "Surface Silvered Ancient Coins," in *Methods of Chemical and Metallurgical Investigation of Ancient Coinage*, edd. E. T. Hall and D. M. Metcalf (London 1972) = *RNS Spec. Pub.* 8 (1972) 261–78, Pll. XIX–XX.

[62] R. W. Wood, "The Purple Gold of Tut'ankhamun," *JEA* 20 (1934) 62–66, Pl. XI.

[63] C. S. Smith, "An Examination of the Arsenic-Rich Coating on a Bronze Bull from Horoztepe," in *Application of Science in Examination of Works of Art*, ed. W. J. Young

One widespread use of precious metals in antiquity was for coinage, a monopoly of the state.[64] Now it seems that in the first century B.C. the incidence of coin forging rose, judging by the Roman law passed against it.[65] The method of fakery in view seems to have been producing pewter (tin–lead alloy) coins. Either plated base metal or substitute alloys could be detected by their lower density, especially if gold was to be imitated. In the case of imitation silver, for which the alchemists give numerous recipes, including at least one involving arsenic,[66] the density problem would not have been so severe—though anyone willing to use Archimedes' method could detect the forgery. Yet coins of very low density made not only of pewter but even of an arsenic or antimony alloy have been found—the earliest examples are from Macedonia, not far from Thessaly and Thrace.[67] Perhaps these developments in the production of imitation silver by the alchemists prompted Menelaus to write his book on the density of alloys in the late first century A.D.[68]

To the alchemical writers (Cleopatra, Maria, Zosimus, etc.) the most important aspect, even of the "scientific" alchemy I have been describing, was the production or imitation of gold. There are numerous recipes, some incomprehensible, some involving merely coloring the surface or debasing the gold with both copper and silver, to preserve the color. By far the most interesting involves another apparatus attributed to Maria the Jewess, the κηροτακίς.[69] Originally a device used by encaustic painters to keep their colored waxes soft, it was used by the alchemists to produce alloys, especially their most successful imitation of gold—a 13% mercury in copper alloy, used until recently by jewelers as a substitute gold. This alloy

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(Boston 1972) 96–102, esp. 102 n. 5; and C. G. Fink and A. H. Kopp, "Ancient Antimony Plating on Copper Objects," *Met. Mus. Studies* 4 (1933) 163–67: Smith explains their error.

[64] Cp. T. R. Martin, *Sovereignty and Coinage in Classical Greece* (Princeton 1985).

[65] P. Grierson, "The Roman Law of Counterfeiting," in *Essays in Roman Coinage Presented to H. Mattingly*, ed. R. A. G. Carson and C. H. V. Sutherland (Oxford 1956) 240–61; p. 242: Sulla's "lex Cornelia de falsis," of 81 B.C. from Ulpian 48. 10. 9.

[66] *PLeydenX* 85 for arsenic; for imitation silver see *PLeydenX* 5, 6, 8–12, 18, 19, 27, 30, etc.

[67] I. A. Carradice and S. La Niece, "The Libyan War and Coinage: A New Hoard and the Evidence of Metal Analysis," *NC* 148 (1988) 33–52, Pll. 7–12 (3rd century B.C. arsenic-alloy Libyan coins); Macedon: *SNG ANS* 8. 86 of Pausanias (ca. 399–93 B.C.) and *SNG ANS* 8. 89 of Amyntas III (ca. 393–69 B.C.) from an unpublished paper by W. S. Greenwalt (ANS, Summer 1987); my own work on the coins in the University of Colorado collection revealed a coin of specific gravity 6.933 ±0.004, which turned out (on microprobe examination) to be composed of a 38% Sb, 60% Sn alloy; the coin is No. 18 of the catalogue of W. and M. Wallace, "Catalogue of Greek and Roman Coins at the University of Colorado," *U. Col. Studies* 25 (1938) 237–80, a triobol of Philip II. Detailed results I hope to publish elsewhere.

[68] J. Würschmidt, "Die Schrift des Menelaus über die Bestimmung der Zusammensetzung von Legierungen," *Philol.* 80 (1925) 377–409.

[69] See Taylor 1930 (above, note 2) 130–38; idem 1949 (above, note 39) 46–50; A. J. Hopkins, "A Study of the Kerotakis Process as Given by Zosimus," *Isis* 29 (1938) 326–54.

cannot be produced by direct amalgamation, but if copper is heated on the palette of the *kerotakis* with mercury vapors below, it first blackens with oxide then whitens as the mercury amalgamates and finally yellows as the heat drives the alloying to completion.[70] In the alchemists' descriptions of the *kerotakis* procedure four changes of color are insisted upon: blackening, whitening, yellowing and "*iosis*." To the final stage I will return in a moment. Another variation, mentioned above, involved the use of tetrasomy ("four-body"), a copper–iron–lead–tin alloy (on which Maria improved by substituting a simpler copper–lead alloy), which was heated over sulfur. This produced a complex black sulfide. A similar process was known in Egypt from New Kingdom times, for making niello—a fused black copper–silver sulfide known to Pliny the Elder in the first century A.D.[71] In any case the reduction of base metal to non-metallic "matter" was necessary, as Aristotle had taught, before any upward transformation was possible. I have mentioned Zosimus' interest in fermentation—this may be explained by reference to alchemical theories in which the black mass was converted to silver then gold by "divine water" whose action is explicitly compared to that of yeast.[72] To this water I would compare Plato's water from which gold forms. Instead of mercury or sulfur, orpiment was sometimes used to act as the yellowing agent.[73]

The final stage, after the yellowing to gold, was *iosis*—which word could mean corruption/rust or purpling. Usually commentators prescind from giving a precise chemical explanation, but the purple gold (containing orpiment) of Tutankhamon perhaps provides a parallel. Is it possible the alchemists were in fact trying to produce purple gold?

Mystical Matters

But we must turn to the *iosis* of alchemy itself—its mystical stage. Why did this occur? As humans we are distinct from the animals by our Faustian urge for the unattainable of which greed is the excess and contentment the defect. Again we are distinguished by our individuality—ape and dog packs show the evolutionary priority of the State (as Eduard Meyer has shown). Mysticism seems to me to be, as religion is, our attempt to deal with our helplessness (to borrow an epigram of Arthur Darby Nock), and in particular it is our ever-vain search for unity both internal and external. We seek the

[70] Cp. Berthelot, *CAAG* II (1887) 146 Greek, 148 French (= Zosimus 3. 1. 1 ff.) and see Taylor (above, note 2) 128, 132–33.

[71] Pliny, *HN* 33. 46. 131 gives the recipe; for discussion see K. C. Bailey, *The Elder Pliny's Chapters on Chemical Subjects* I (London 1929) 227; Lucas (above, note 9) 249–51 and A. A. Moss, "Niello," *Studies in Conservation = Etudes de conservation* 1 (1953) 49–62.

[72] Cp. Berthelot, *CAAG* II (1888) 145, 248 Greek, 147, 238 French (= Zosimus 3. 10. 5 and 52. 4). Cp. note 32 above.

[73] Berthelot, *CAAG* I (1887) 67, 238–39, 264; II (1888) 44 Greek, 47 French (= Bolus, *Phys. Myst.* 7); II (1888) 163–64 Greek, 163 French (= Zosimus 3. 16. 11).

inner integration of our personality (as Freud and Jung meant) and the outer integration of our selves into society (the subject of countless works of sociology and the subtext of the Herodotean story of the tyrant knocking off the heads of all the oustanding grain: 5. 92. ζ. 2–η. 1)—that is we seek an impossible return to our bestial past. The current of this feeling is part (perhaps even one of the chief parts) of the transformation which overwhelmed Mediterranean culture between 180 and 280 A.D.—I mean (with Peter Brown, Alexander Demandt, Hans-Peter L'Orange and Samuel Sambursky) the change from the Classical or Greco-Roman world to the Late Antique world.[74] The Late Antique Period runs roughly from 280 to 640 A.D. and is characterised by the ascendancy of the transcendant. One can see this change in all aspects of life—religion (and Christianity did not cause but suffered from this change), philosophy (I need only mention neo-Platonism), government (the reforms of Diocletian imposed ca. 285 A.D. laid the foundation of the Middle Ages), architecture (the use of vast internal space in the basilica churches), and art. Perhaps in sculpture it is most clear: though I am not an art historian, I follow L'Orange here. Classical statues and busts are balanced and confident and gaze forthrightly at the viewer; one can sense their humanity. In the famous Delphic Charioteer of the early fifth century B.C. the face is modeled naturally, the lips are parted as if about to speak, the eyes are forward, focused on what must have been the horses. The portraits of Constantine are well known for their Late Antique characteristics and mark in a way the culmination of the trends: note the stark planes of the face, outlined with pure curves at the eyebrows and the face itself suffused with an otherworldly look while the eyes are directed towards heaven. Busts of the second and third centuries A.D. show pure curves in the face; all such seem to portray figures unaware of the viewer or his world.

I have tried to convey all too briefly an impression of this overwhelming paradigm shift in the ancient world—alchemy too underwent this shift and transformed from a scientific (if erroneous) search for transmutation into a mystical search for personal transformation. What were the internal roots of this, what background can we find for understanding chemistry as mysticism?

Democritus, the pre-Socratic philosopher to whom is attributed the ancient theory of atoms, the same under whose name Bolus wrote, connected the atoms making up the soul with those of fire or of the sun.[75] While

[74] H.-P. L'Orange, *Studien zur Geschichte des spätantiken Porträts* (Oslo 1933) and *Civic Life and Art Forms in the Late Roman Empire* (Princeton 1965); S. Sambursky, *The Physical World of Late Antiquity* (Princeton 1962); P. Brown, *The Making of Late Antiquity* (Cambridge, MA 1978); A. Demandt, *Die Spätantike* (Munich 1989).

[75] D. L. 9. 44, Democr. frr. A74, A135 D–K. See also W. Burkert, *Lore and Science in Ancient Pythagoreanism*, tr. Edwin L. Minar, Jr. (Cambridge, MA 1972) 357–68; P. Boyancé, "La religion astrale de Platon à Cicéron," *REG* 65 (1952) 312–50; and F. Cumont, "Les noms des planètes et l'astrolâtrie chez les Grecs," *Ant. Class.* 4 (1935) 1–43.

Democritus was no atheist (they were a great rarity in the ancient world), other Greeks saw "danger" in Democritus' attempt to explain the world atomistically (it seemed to remove the gods too far). Yet this particular point was something of a commonplace—Plato in the *Timaeus* explicitly connects human souls and the stars[76] putting them into one-to-one correspondence, while other philosophers including Aristotle put forward hypotheses about the substance of souls and stars such that by the first century B.C. they were more or less equated.[77] Hipparchus the great astronomer who discovered the precession of the equinoxes in about 130 B.C. was praised because he proved that the stars are kindred with man and our souls are part of the heavens.[78] Instead of being made of this quintessence, the mind or soul could also be thought of as the mixing of the elements or atoms, and the perfection of the soul as the proper mixing or balancing by means of the stellar substance, the quintessence. In any case, the philosophic notion of perfecting the soul was that the soul's true divine nature must be brought out.

Plato had already compared the soul to gold in a famous passage in the *Symposium* (216d–17b)—the soul, that is, of a good man, Socrates. Gold was, since Babylon, the metal of what even Pindar had called the warmest star (*Oly.* 1. 6)—and most ancient Greeks knew that the stars were fiery. Thus it was only logical—the perfect soul is purified, made heavenly, made golden, as even Pindar in that same Victory Song had sung (*Oly.* 1. 1). The idea must be nearly universal, as it is even found in the Hebrew Scriptures, in the *Psalms*, where the Law of God, which perfects the soul, is better than gold, even much fine gold.[79] In *Proverbs* and in the prophets God working on the soul is compared to a refiner seeking to cleanse the noble metal of its dross.[80] And this salvation is explicitly compared to purification of gold and silver by fire when Paul writes to the Corinthians:[81] "If anyone's work is burned up having been penalised he will be saved, but just as through fire."[82] The prevalence of the worship of the Unconquered Sun[83]—which went so far that Christians adopted the birthday of the Sun (the Winter Solstice) as the birthday of the Son of God—may have had an influence, since the Sun is the planet whose metal is gold. There is also no doubt some original connection to the Golden Age of Hesiod, from which the human race has subsequently declined through Silver (and Copper) to Black

[76] *Tim.* 41–43; see A. E. Taylor, *Commentary on Plato's Timaeus* (Oxford 1928) 255–58.

[77] See above, note 34.

[78] M. P. Nilsson, *Rise of Astrology in the Hellenistic Age* (Lund 1943); Pliny, *HN* 2. 24. 95.

[79] *Psalm* 119; cp. also *Psalm* 66. 10.

[80] *Proverbs* 17. 3, 27. 21, *Wisdom* 3. 6; and *Isaiah* 1. 25, *Jeremiah* 6. 27–30, *Ezekiel* 22. 17–22, *Malachi* 3. 2–3. I am indebted to C. G. Estabrook (U. of Illinois, Religious Studies) for finding some of these passages for me.

[81] I *Corinthians* 3. 11–15.

[82] Cp. also II *Peter* 3. 10.

[83] See F. Cumont, "La théologie solaire du paganisme romain," *Mémoires. Académie des Inscriptions et Belles-Lettres* 12. 2 (1909) 448–79; cp. even Cicero, *Somnium Scipionis* 4.

Iron.[84] Not surprisingly the alchemists, as had their philosophical forebears, sought to reverse this: black, white silver, yellow gold—and even to outdo it—with the transcending *iosis*.

In any event the transformation happened: what had begun as an experimental science founded on the best scientific thought of the age—Aristotle's four-element theory—became a search for personal transformation. Let me cite some highlights.

Zosimus in his vision sees the Man of Copper becoming the Man of Silver and thence the Man of Gold: again immortality is promised to souls capable of entering into the secrets of heaven.[85] Contemporary with Zosimus are two alchemical papyri, really recipe books (cited above), and found in a grave with other magical and Gnostic papyri.[86] A bit earlier the Christian Bishop Hippolytus had associated alchemical recipes, including that for distilled alcohol, with the magical tricks of the Gnostics. One group of Gnostics is even credited with obtaining gold from bronze.[87] Gnosticism was the first successful Christian heresy, in which the essence of salvation lay in learning the secret Gnosis—just as for the alchemist—by which the immortal and spiritual soul could shrug off the merely physical dross of the body and rejoin the purely spiritual Logos.[88] Usually this Gnosis is revealed in some vision or ritual—note the vision of Zosimus and the ritual enacted by Bolus to attempt to gain the secret knowledge of his dead master.[89] I have already suggested how some of these apparently alchemical ideas are to be found in the New Testament; later Christian thought was also sometimes influenced—in the *Martyrdom of Polycarp* (15. 2) we read how when he was burned he seemed as if he were gold in the refiner's fire (or bread baking). We may also note the prominence in both Gnosticism and alchemy of the snake Ouroboros.

Later we have writers who are explicitly Christian and explicitly alchemists—Stephanus of Alexandria in the seventh century A.D., for example.[90] He writes:[91]

[84] Hesiod, *W&D* 106–210; cp. *Daniel* 2. 31 ff.

[85] Berthelot, *CAAG* II (1888) 229 ff. (= Zosimus 3. 51. 8); cp. R. Reitzenstein, *Poimandres* (Leipzig 1904) 103 ff.

[86] Forbes, *SAT* I (1964) 141; H. J. Sheppard, "Gnosticism and Alchemy," *Ambix* 6 (1958) 86–101, esp. 93–98.

[87] Wilson (above, note 54) 164.

[88] K. Rudolf, *Gnosis* (New York 1983) 55–56, 113–18; Thorndike (above, note 39) 360–84.

[89] A. J. Festugière, *La révélation d' Hermès Trismégiste* (Paris 1950) I 217–82; Sheppard (above, note 86) 86; idem, "The Redemption Theme and Hellenistic Alchemy," *Ambix* 7 (1959) 42–46; J. Scarborough, "Gnosticism, Drugs and Alchemy in Late Roman Egypt," *Pharmacy in History* 13 (1971) 151–57; M. Mertens, "Une scène d'initiation alchimique: La 'Lettre d'Isis à Horus'," *RHR* 205 (1988) 3–24 (a reference I owe to Maryline Parca).

[90] F. S. Taylor, "The Alchemical Works of Stephanos of Alexandria," *Ambix* 1 (1937) 116–39, 2 (1938) 38–49.

[91] Taylor 1937 (previous note) 129.

> "For the emanation of it is the mystery hidden in it, the most worthy pearl, the flame-bearing moonstone, the most gold-besprinkled chiton, the food of the liquor of gold, the chryso-cosmic spark, the victorious warrior, the royal covering, the veritable purple, the most worthy garland, the sulphur without fire, the ruler of the bodies, the entire yellow species, the hidden treasure, that which has the moon as couch, that which in the moon is gnostically seen as [here follows a series of 10 incomprehensible symbols] . . ."

What does this mean? Elsewhere Stephanus writes as a Pythagorean (Lecture 2):[92]

> "The multitude of numbers compounded together has its existence from one atom and natural monad; this which exerts a mutual tension comprehends and rules over the infinite as emanating from itself. For the monad is so called from its remaining immutable and unmoved. For it displays a circular and spherical contemplation of numbers like to itself, I mean a completion of the five numbers and of the six."

And (Lecture 1):[93]

> "You the whole are the one nature, the same by which the whole becomes the work. For by an odd number [preferred by the Pythagoreans] thy all-cosmos is systematised. For then you shall understand . . . then you shall discover . . ."

and so on. Elsewhere he writes as a Gnostic (Lecture 1):[94]

> "Put away the material theory so that you may be deemed worthy to see with your intellectual eyes the hidden mystery. For there is need of a single natural thing and of one nature conquering the all. Of such a kind, now clearly to be told you, that the nature rejoices in the nature and the nature masters the nature and the nature conquers the nature."

And he exhorts his hearers to a Christian alchemy (Lecture 1):[95]

> "Alone we are made friends with him by Love, and we receive from him the wisdom springing forth as an abyss from the abyss [so a Gnostic would say] that we may be enabled by the grace of our Lord Jesus Christ to gush forth rivers of living water."

The connection is that "copper like a man has both soul and spirit"—air gives us our spirit, fire gives it to the copper.

A bit later the poet-philosopher Theophrastus (*fort.* eighth century A.D.) writes that the object of alchemy is to pour the unchangeable matter from the form of lead into the form of gold—he compares a sculptor working bronze, but I am reminded also of Paul's image in the letter to the

[92] Taylor 1937 (above, note 90) 127.
[93] Taylor 1937 (above, note 90) 123.
[94] Taylor 1937 (above, note 90) 123.
[95] Taylor 1937 (above, note 90) 125.

Romans of the divine potter molding souls, and of the image of Plato in the *Timaeus* of the craftsman molding golden statues.[96]

So much for mysticism—what has all this to do with us? We live in a scientific and post-Christian age, do we not? Not entirely—there is much pseudo-science about, and three great figures were heavily influenced by alchemy: I mean Newton, Goethe and Jung. Newton regarded alchemy as a part of his intellectual life as important as his work on gravitation, and tested recipes for obtaining gold from sulfur and mercury.[97] Goethe, though living in the age of Lavoisier and Priestley at the dawn of modern scientific chemistry, believed in alchemy in the sense of obtaining mystical substances with transmutative powers.[98] Goethe's belief was that "as Nature works in particular things, so also does she work in universal things," that there is a symmetry in all parts of Nature animated by one Spirit—this is wholly Stoic. Within this there are pairs of polar opposites and the goal of alchemy is to produce an incorruptible permanence embracing all opposites, achieved by a descent to death and corruption, followed by an ascent—the links to ancient (and medieval) alchemy are plain, but all that is left is the magical and mystical aspect. Jung's interest in alchemy and Gnosis extended to the purchase of one of the Nag Hammadi Gnostic codices; in his seventeen volumes of collected works, fully three are devoted to alchemy (only one to the collective unconscious). He translated and commented on the Visions of Zosimus cited above—he connects the symbolism of alchemy and the structure of the unconscious.[99] I do not pretend to understand it.

All three of these men have influenced our modern world, which itself shows evidence of mankind's continuing fascination with the mystical.[100] Not long ago an article appeared in the prestigious scientific journal *Nature* in which it was claimed that solutions of certain antigen-proteins diluted by such a factor that it was not possible that even one molecule of the protein

[96] C. A. Browne, "The Poem of the Philosopher Theophrastus Upon the Sacred Art: A Metrical Translation with Comments Upon the History of Alchemy," *Scientific Monthly* 11 (1920) 193–214; for date see H. Hunger, *Die hochsprachliche Profane Literatur der Byzantiner* II (Munich 1978) 280.

[97] Most recently, R. L. Gregory, "Alchemy of Matter and Mind," *Nature* 342 (1989) 471–73; see also: I. B. Cohen, "Newton," *DSB* 10 (1974) 81–83, 100; P. M. Rattansi, "Newton's Alchemical Studies," in *Science, Medicine and Society*, ed. A. G. Debus (London and New York 1972) II 167–82; J. E. McGuire, "Transmutation and Immutability," *Ambix* 14 (1967) 69–95; D. Geoghegan, "Some Indications of Newton's Attitude Towards Alchemy," *Ambix* 6 (1958) 102–06; A. R. and M. B. Hall, "Newton's Chemical Experiments," *AIHS* 11 (1958) 113–52; F. S. Taylor, "An Alchemical Work of Sir Isaac Newton," *Ambix* 5 (1956) 59–84; R. J. Forbes, "Was Newton an Alchemist?," *Chymia* 2 (1949) 27–36.

[98] I depend for Goethe's alchemy on R. D. Gray, *Goethe the Alchemist* (Cambridge 1952).

[99] See *The Collected Works of C. G. Jung* XIII: *Alchemical Studies* (New York 1968) 59–108 for Zosimus (vols. XII–XIV are concerned with alchemy).

[100] Cp. T. Hines, *Pseudo-Science and the Paranormal* (Buffalo, NY 1988); A. G. Debus, "Science vs. Pseudo-Science: The Persistent Debate," in *Chemistry, Alchemy and the New Philosophy* (London 1987) 1–18.

was present in a liter of solution yet continued to display antigen activity. This "naturopathic" claim was soon refuted (it seems the naturopath on staff had "subconsciously" fudged the statistics), but new naturopathic clinics spring up like mushrooms. Activists oppose the use of animals in research on the grounds that "a rat is a pig is a dog is a boy"—this is a Pythagorean argument. Belief in reincarnation, a cardinal Pythagorean tenet, is widespread (as Herodotus did in another connection, I omit to mention the name of the Californian well known for this). Alchemy, palm-reading, tarot cards and the like are no longer so popular—but "channeling" is, and need I mention that every newspaper feels obliged to publish horoscopes, read religiously by millions?

Our age has witnessed the old dream of the alchemists become a reality. Transmutation is possible, and I myself have used one such artificial element in my scientific chemical research—Technetium, element 43, with a half-life of some 200,000 years. It is unnerving, to say the least, to discover that American foreign policy has been directed by astrology in an age enlightened by nuclear fires, fires produced by the transmutation of Uranium (named after the first new planet to be discovered) into Plutonium (named after the third new planet). In such a context the scientific study of ancient alchemy may be very enlightening indeed. And so I end where I began, with the Promethean fire for having which the gods damn us, and:

> "What shall I build or write
> Against the Fall of Night?"[101]

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[101] A. E. Housman, *More Poems* 45. 11–12. I am indebted to Sarah Wissemann for discussions on the history of metallurgy and several references (Rapp [above, note 12], Tylecote [above, note 9] and Vandiver et al. [above, note 6]), and to W. M. Calder III for critical readings and stylistic advice.

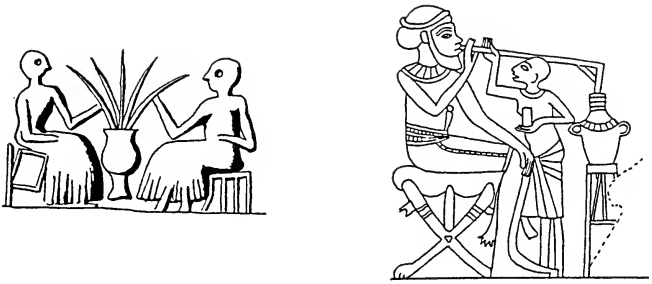

Fig. 1
Sumerian and Egyptian Beer-drinking (note straws).
(After Hartmann and Oppenheim, *JAOS* Suppl. 10 (1950) Pll. I.1, II.2)

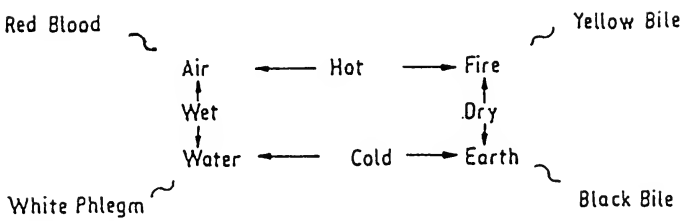

Fig. 2
Table of the Four Elements and Humors.
(After Keyser, *Philol.* 133 [1989] 79)

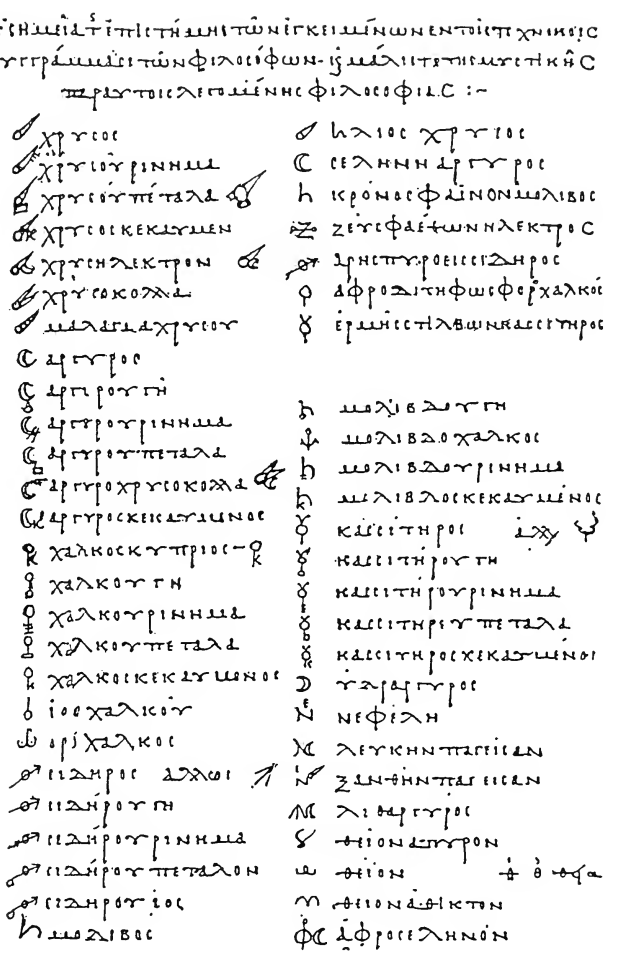

Fig. 3
Planetary Symbolism in Alchemy (*MS Marcianus* 2327, f. 6).
(After Berthelot, *CAAG* I [1887] 104)

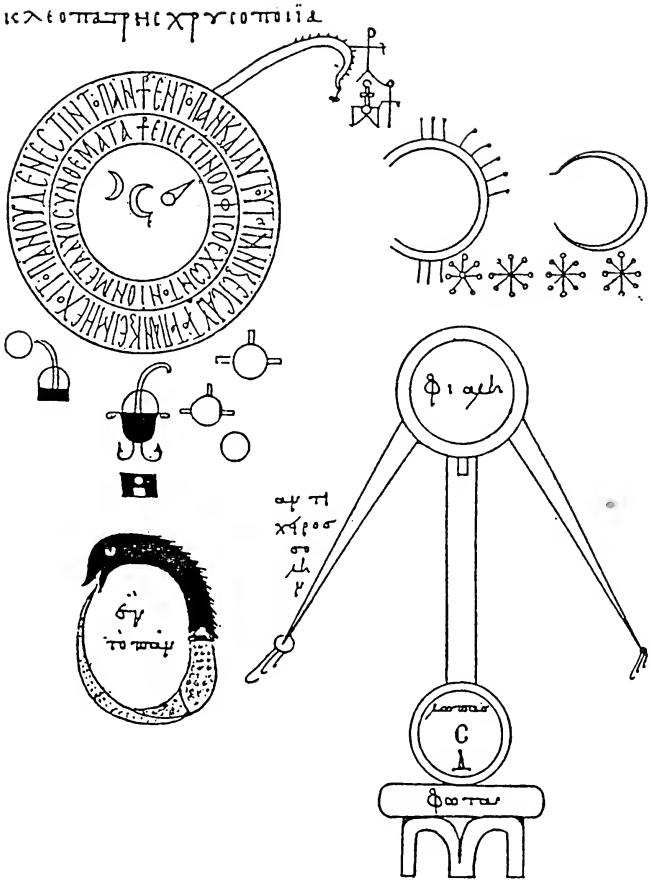

Fig. 4
Chrysopoeia of Cleopatra (*MS Marcianus* 2327, f. 188ᵛ).
(After Berthelot, *CAAG* I [1887] 132)

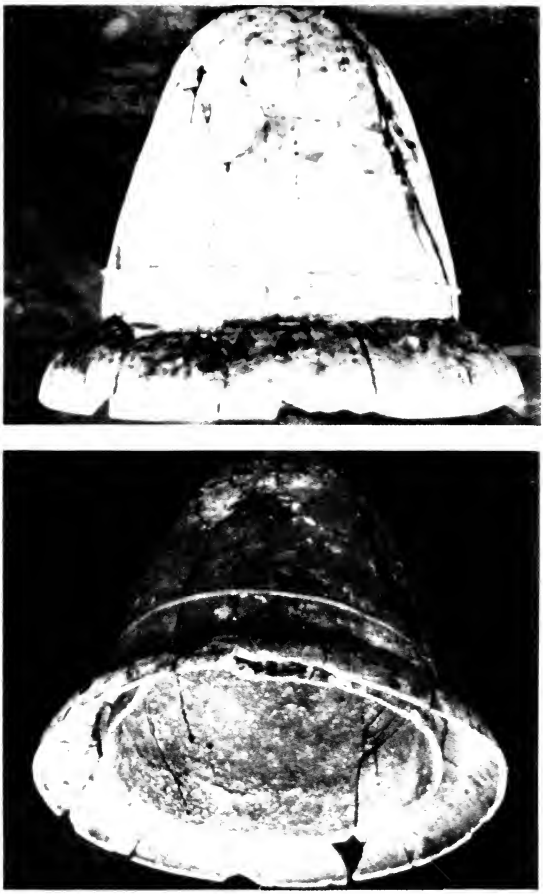

Fig. 5
Sumerian Still from Tepe Gawra (ca. 3500 B.C.).
(After Levey, *Centaurus* 4 [1955] Pl. facing. p. 24)

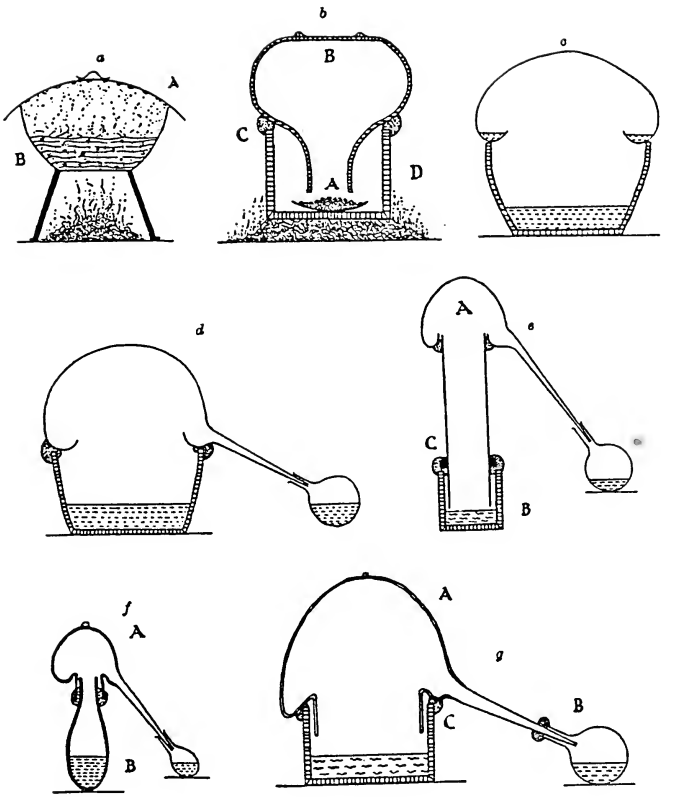

Fig. 6
Stages (a through g) in the Evolution of the Still.
(After Taylor, *Annals of Science* 5 [1945] 201, Fig. 14)

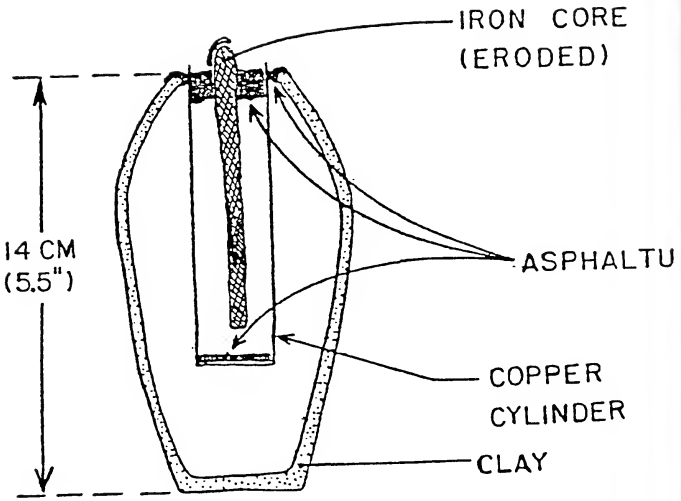

Fig. 7
Parthian Electric Battery (Copper–Iron Wet Cell).